

# ***GAME THEORY FOR GREEN AVIATION***

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## ***CONTEXT***

- *The NAS has many subsystems that are*
  - i) highly complex*
  - ii) highly coupled*
  - iii) have clear objectives*
- *Examples of such subsystems:*
  - i) Artificial, e.g., automated separation assurance*
  - ii) Human, e.g., airplane pilots*
  - iii) Groups, e.g., airlines making flight plans*

## ***CHALLENGE***

*Using knowledge of subsystem objectives,  
make statistical prediction of full system behavior*

- 1) Statistical prediction often very useful by itself*
- 2) It is necessary for optimal  
control of an existing system*
- 3) It is necessary for optimal  
design of a new system*

## ***TECHNICAL HURDLE***

- 1) Machine learning makes statistical predictions***
    - does not exploit knowledge of subsystem objectives***
  - 2) Game theory exploits knowledge of subsystem objectives***
    - does not make statistical predictions***
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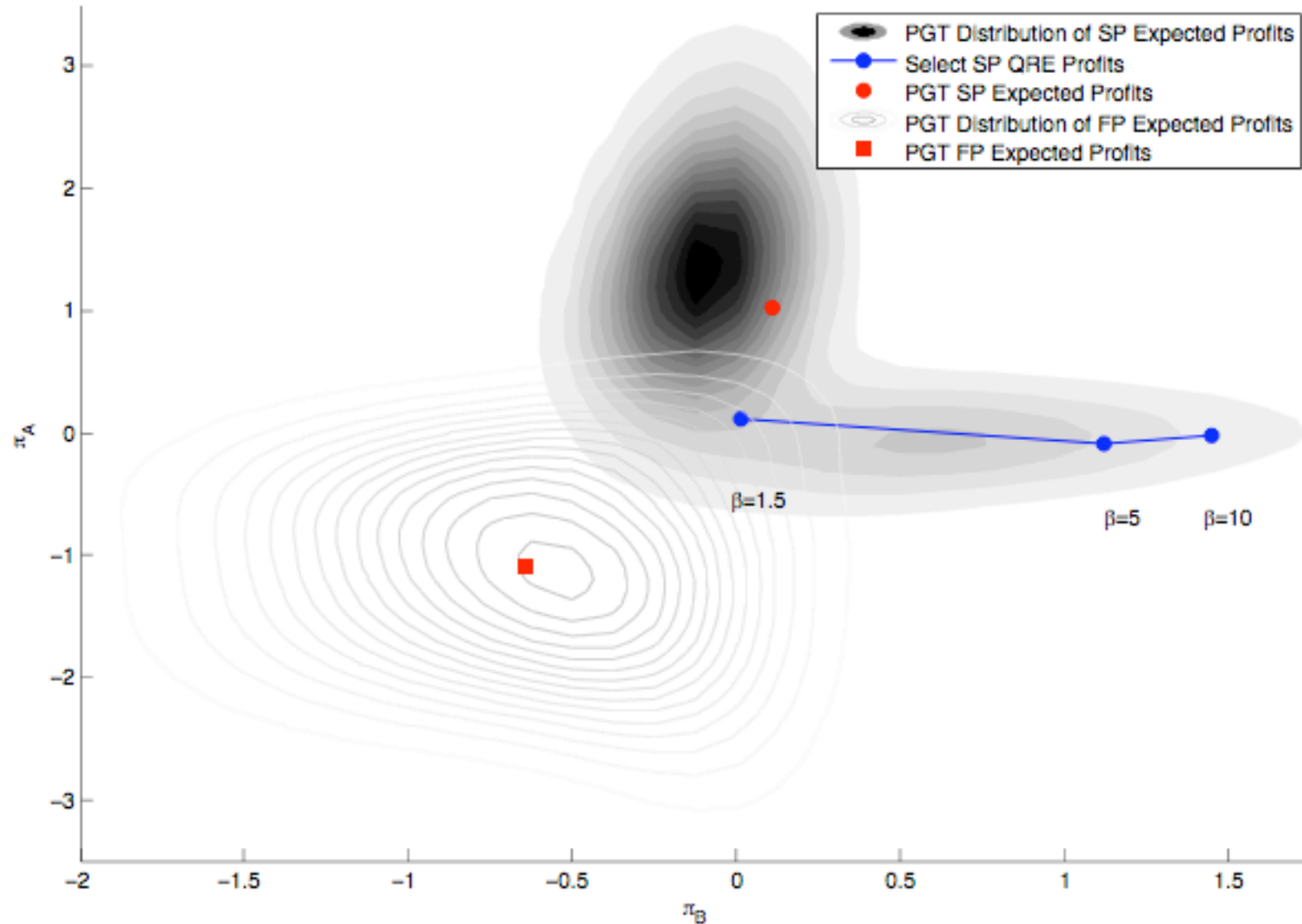
***So ... combine machine learning and game theory:***

**Predictive Game Theory (PGT)**

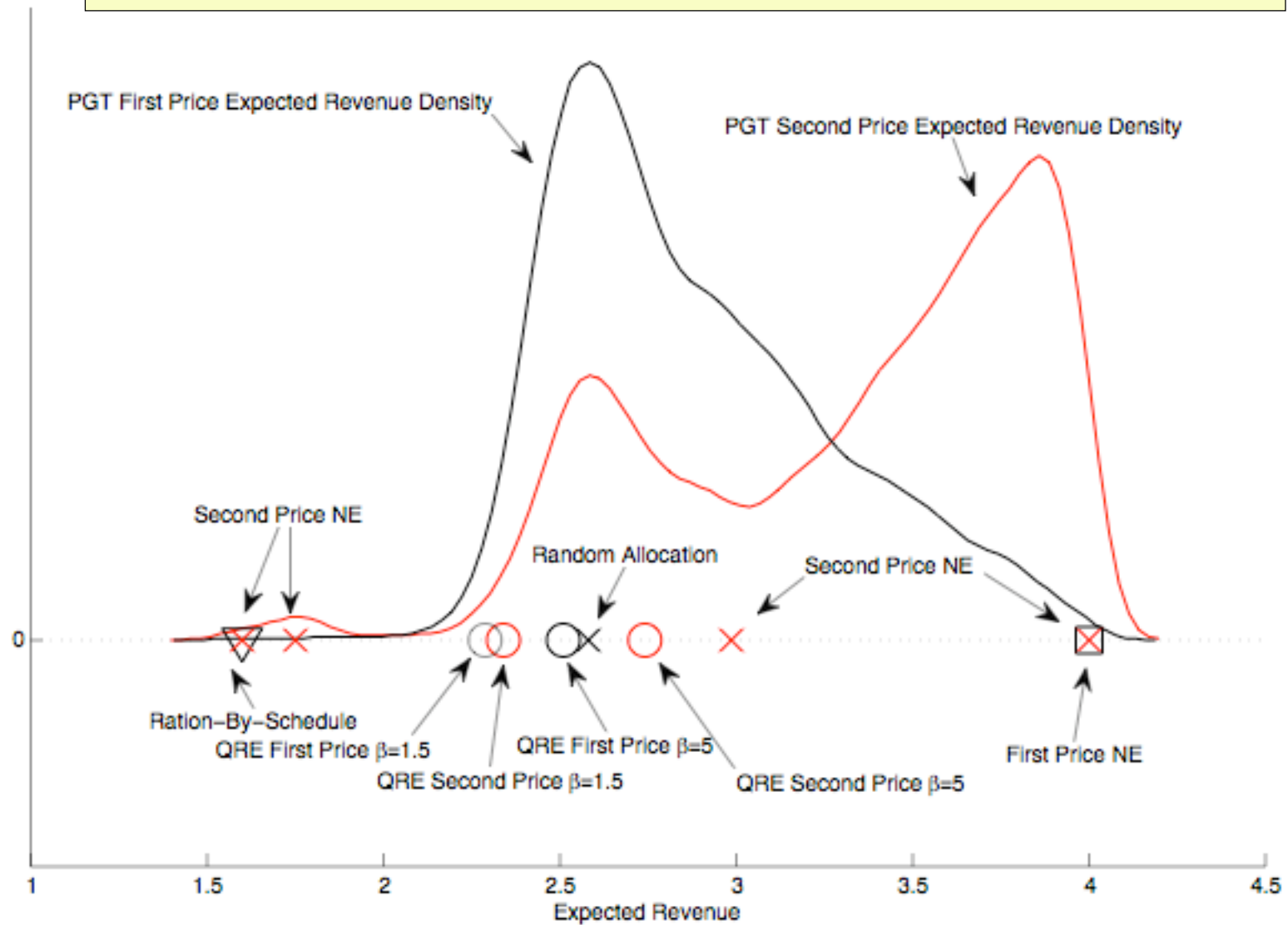
**EXAMPLE 1:**  
***Game theory for ground delay programs***

- **Distributed system:** *Airlines making auction bids for airport arrival slots during a ground delay program*
- **Subsystems:** *The airlines*
  - 1) *Using PGT, can predict system behavior for any {auction design}*
  - 2) *So for optimal design, find {auction design} that maximizes total airline profit (and/or minimizes total fuel use, CO<sub>2</sub> emissions, etc.)*

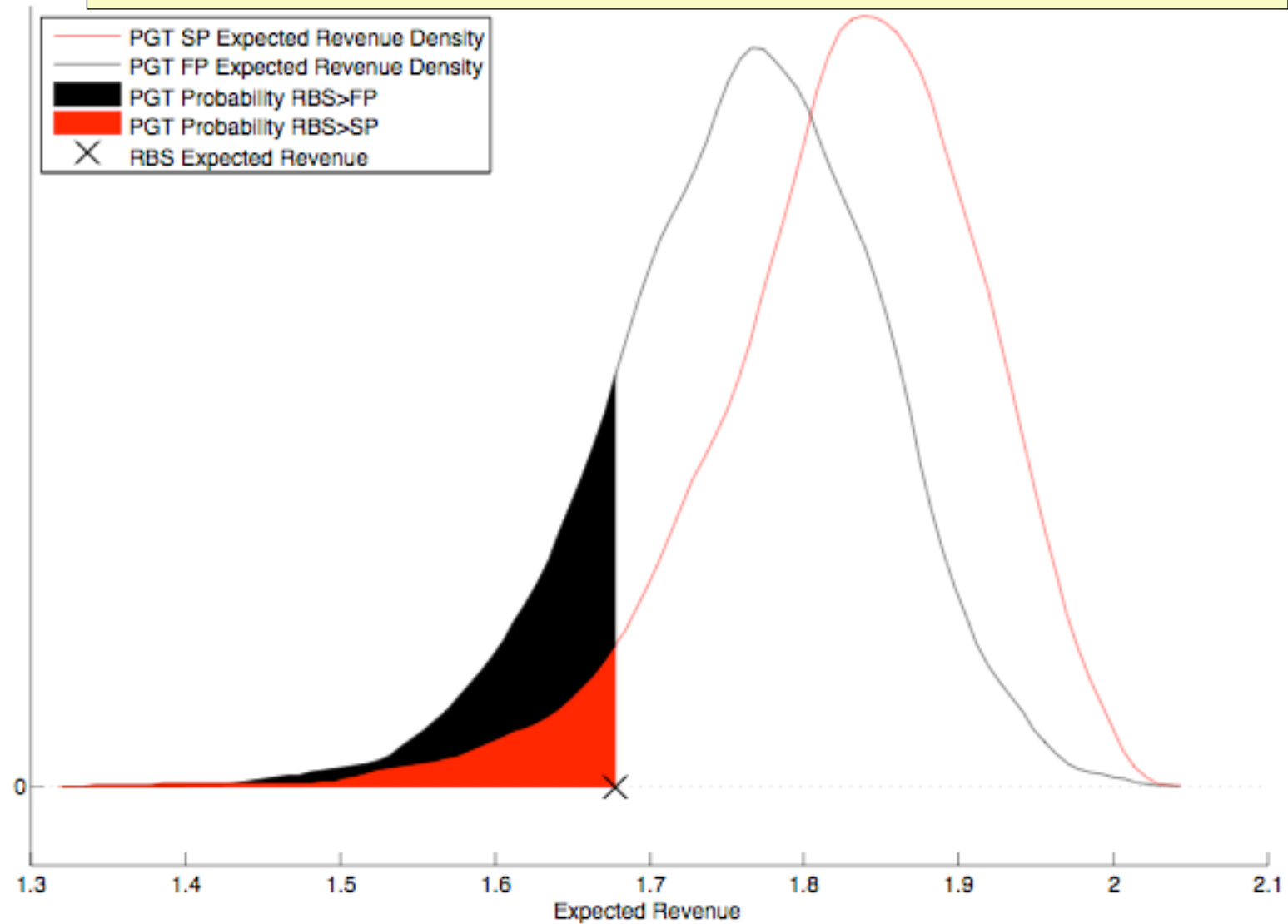
# *Distributions of expected profits*



# *Distributions of expected total revenue*



## *Probability of losing to current system*



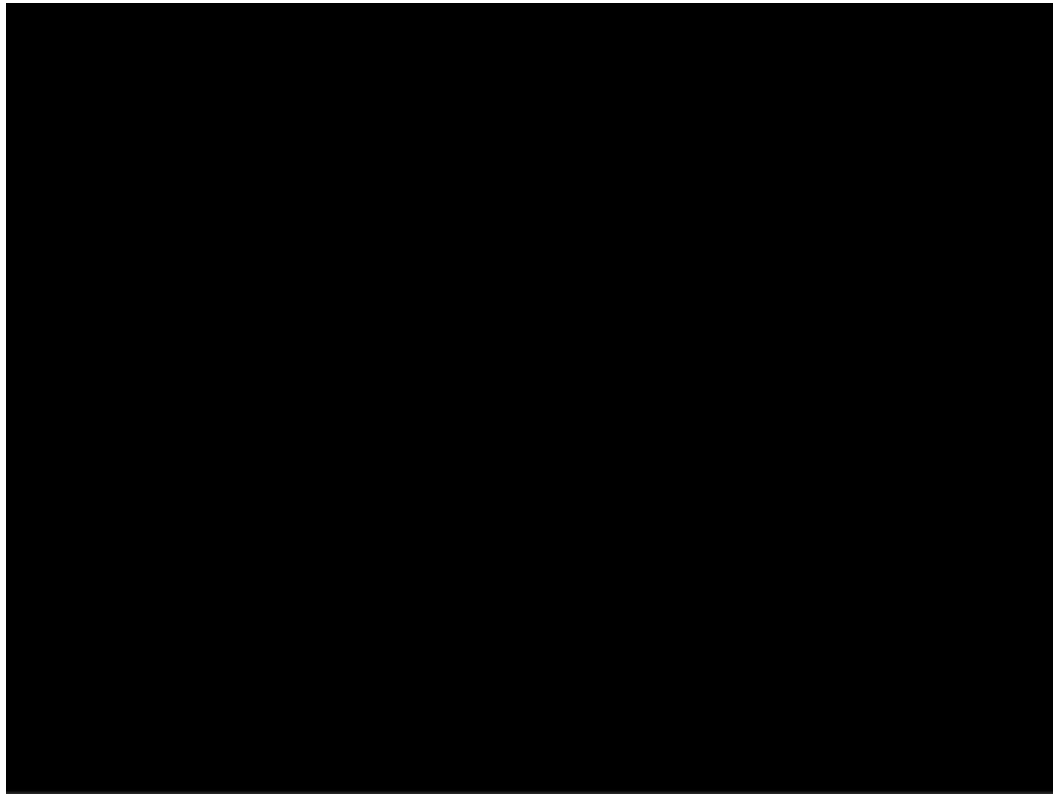


**EXAMPLE 2:**  
***Game theory for distributed system control***

- **Distributed system:** *Airplane wing with trailing edge microflaps*
  - **Subsystems:** *The microflaps, each running a separate controller with a separate objective*
- 1) *Using PGT, can predict system behavior for any set, {subsystem objectives}*
  - 2) *So for optimal flutter control, adapt {subsystem objectives} to minimize wing flutter*

***EXAMPLE 1:***

***Game theory for distributed system control***

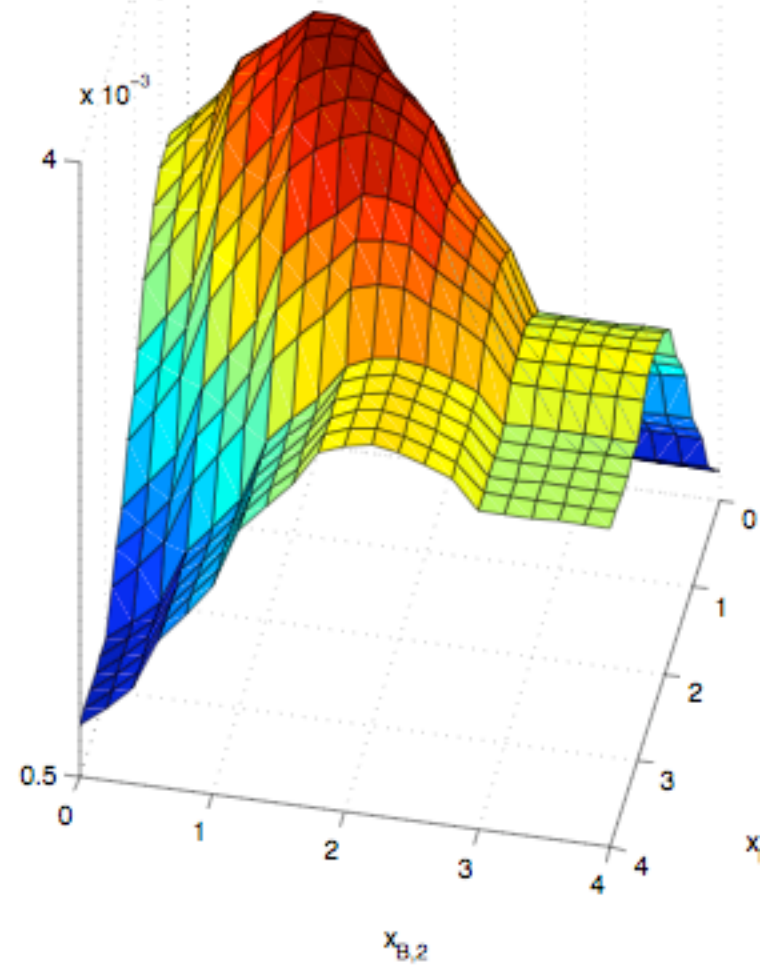
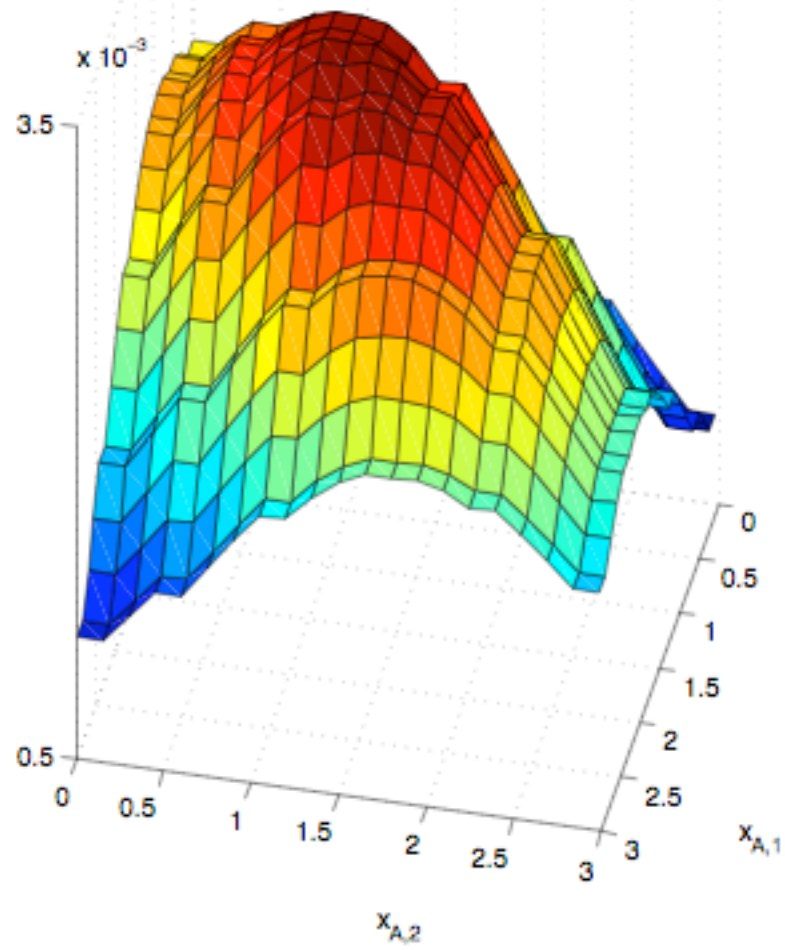


## *ILLUSTRATION OF GAME THEORY APPROACH*

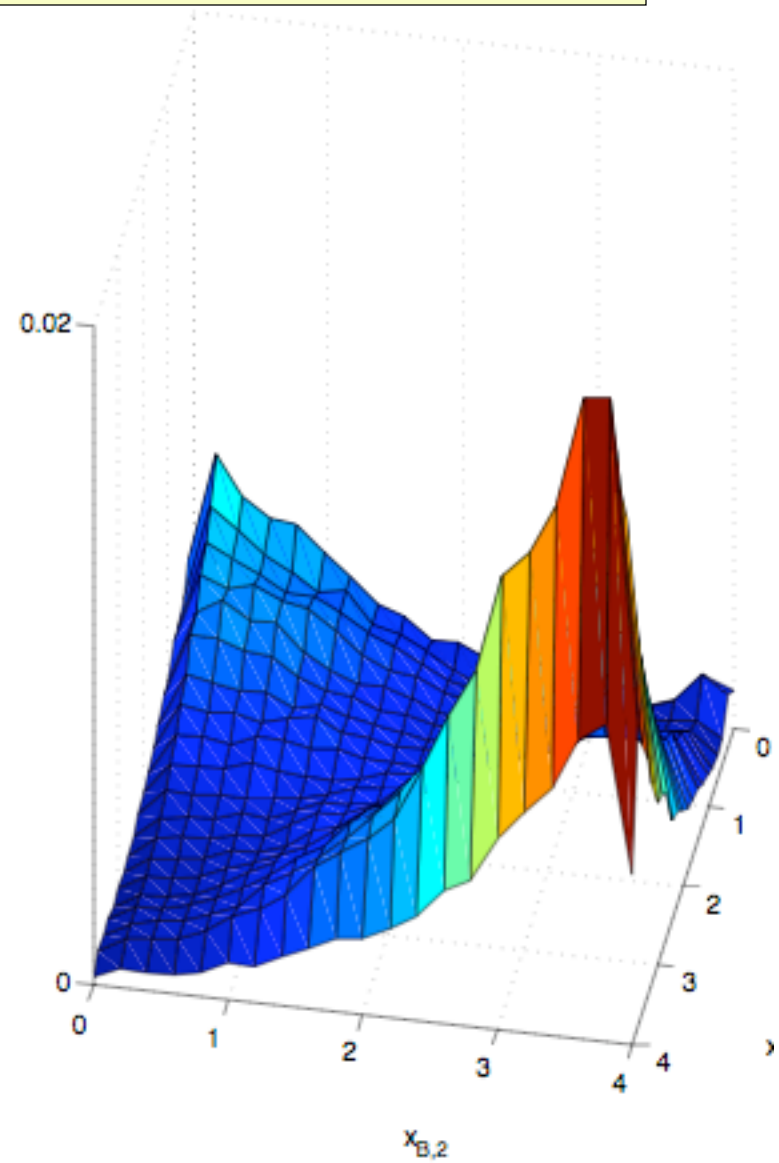
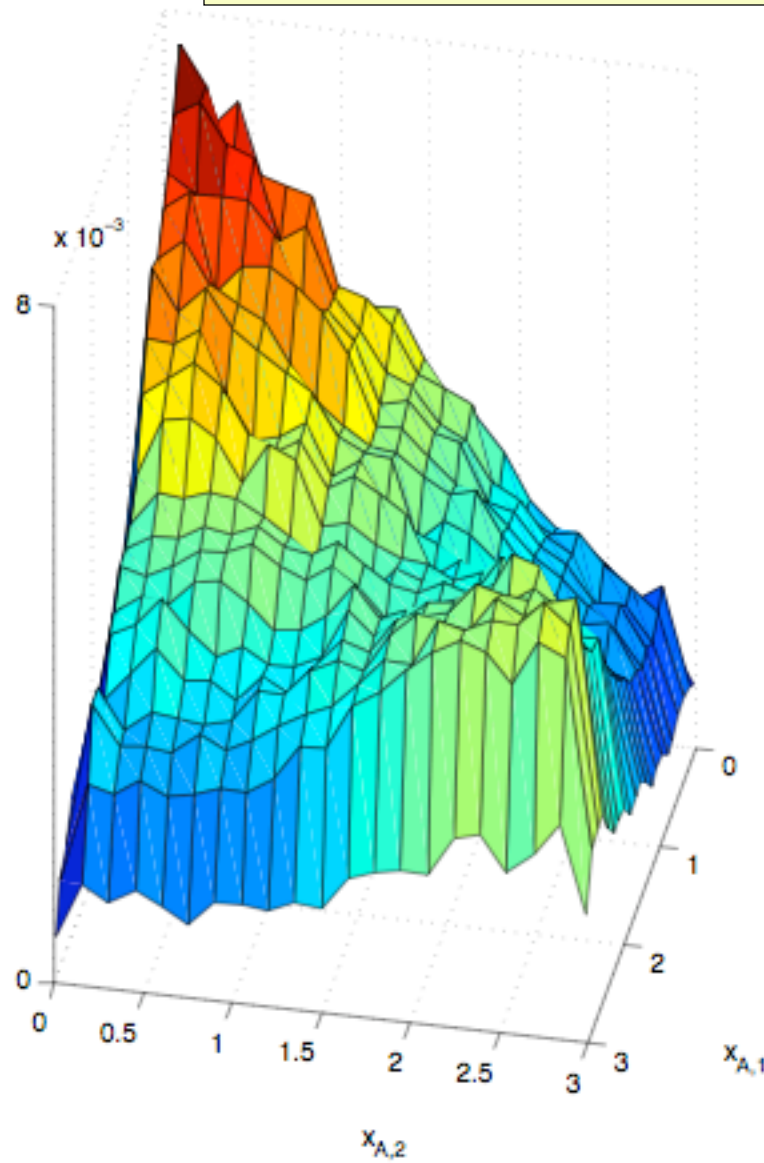
<i>0,6</i>	<i>4,7</i>	<i>-1,5</i>	<i>4,4</i>
<i>-1,6</i>	<i>5,5</i>	<i>2,3</i>	<i>7,4</i>
<i>-2,1</i>	<i>3,2</i>	<i>0,0</i>	<i>5,-1</i>
<i>1,1</i>	<i>6,0</i>	<i>1,-2</i>	<i>6,-1</i>

- **Red** is the equilibrium for original objective functions
- **Blue** is the equilibrium for “negative” objective functions

## *QRE pdf's of each airline's bids*



## *PGT pdf's of each airline's bids*



## ***APPLICATIONS***

1) *Coordinating design teams to design a vehicle (MDAO).*

*Subsystems are the design teams*

2) *Coordinating humans in air traffic management, airport operations, mission control, etc.*

*Subsystems are the separate humans*

3) *Coordinating separate controllers on a hypersonic vehicle.*

*Subsystems are the separate controllers*

4) *Coordinating airline flight plans during weather disruptions.*

*Subsystems are the separate airlines*